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Hazards of Microwave Radiations - A Review

Since World War II, radar and other microwave equipment have come into use by the Armed Forces, commercial aviation, navigation, and to a lesser extent, by medical science. While it is generally believed that microwaves in these applications are harmless, sporadic reports of injuries attributed to microwaves are in the literature.

The term microwaves is used to designate a certain portion of the electromagnetic spectrum; it generally includes frequencies between 1000 and 30,000 megacylces per second, or in terms of wave length, between 30 cm and one cm.

Two radar bands are now in common use: the "S" band, with a frequency of 2880 megacycles and a wave length of 10.4 cm, and the "X" band, with a frequency of 9375 megacycles and a wave length of 3.2 cm.

Microwaves are used in clinical medicine as a means for heating tissues beneath the skin and subcutaneous fatty layers. The diathermy application depends on the fact that heat is produced wherever microwave or any other energy is absorbed.

Microwave diathermy machines typically have a frequency of 2450 megacycles, a wave length of 12.2 cm, and a power output of 125 watts.

Absorption of Microwave Energy in Tissue. Any biologic effect, beneficial or harmful, produced by microwaves can result only from absorption of energy by the tissues. The amount of energy absorbed by a small volume of tissue in a large mass of tissue subjected to microwave radiation depends on a number of factors:

1. Intensity or field strength of the microwave radiation incident on the surface of the tissue mass
2. Duration of the exposure
3. Frequency or wave length of the microwave radiation
4. Thickness of tissue between the irradiated surface and the small volume of tissue
5. Composition of the tissue

The degree of temperature rise produced in the small volume of tissue will depend on the five factors above and on the ability of the irradiated portion

of tissue to rid itself of excess heat. It should be noted particularly that the energy deposition in tissue is dependent on microwave frequency and on composition of the tissue.

Biologic Effects of Microwaves. On purely physical grounds, it can be said that absorption of energy from microwaves or from any other penetrating radiation will raise the temperature of the absorbing material. If the absorbing material is the tissue of a living mammalian organism, the temperature elevation will set in motion a complex sequence of homeostatic mechanisms that tend to restore the normal temperature. Under steady state irradiation conditions, an equilibrium will be attained at a temperature somewhat higher than normal. The human body is capable of dissipating heat at a rate on the order of 0.01 to 0.1 watts per square centimeter of body surface. Thus, the average human body is able to absorb between 100 and 1000 watts of energy from an outside source like microwaves while still maintaining an equilibrium, but an elevated temperature. Higher rates of energy absorption will overpower the regulatory capabilities of the body and lead to a continuous temperature rise and, ultimately, death.

All tissues of the body are not equally equipped for heat dissipation and temperature regulation. The lens of the eye and hollow viscera, such as gallbladder, urinary bladder, and parts of the gastrointestinal tract, for example, are comparatively avascular and largely devoid of effective temperature regulating mechanisms. It is reasonable to expect that such organs will suffer relatively larger temperature rises and will be more liable to injury by microwave irradiation than other body organs. Experiments have, in fact, shown that severe and injurious temperature increases occur in these organs under microwave irradiations accompanied by only slight increases in rectal and oral temperature.

It is not clear whether all biologic effects of microwaves can be attributed solely to temperature increases that result from energy absorption, or whether these effects are produced in part by mechanisms other than simple thermal elevation. Hines and Randall were unable to find any crucial experimental evidence for biologic effects unrelated to temperature change. It should be pointed out, however, that at this time it is impossible to rule out completely the possibility of athermal effects of microwaves.

Experimental Evidence in Laboratory Animals. Hines and Randall in 1952, reported the pronounced effects of high intensity 10 cm microwaves on laboratory animals. Rabbits exposed to a constant 3000 watt field for 75 seconds were killed instantly, and a 30 second exposure produced death within 2 minutes after irradiation was terminated. At this same power level, a rat was killed by a 22 second exposure. A hamster exposed to a 400 watt field died immediately after a 10 second exposure. These lethal effects are attributed to a generalized increase in body temperature which ultimately

leads to a thermal paralysis of the respiratory center. Irreversible cellular injury and death may occur when tissue temperature is maintained 5 C above the normal body temperature. Irreversibility of the injury depends on duration of the hyperthermic episode; the higher the temperature the shorter the time necessary to cause cell death.

It was observed that when only a limited area of the body, such as the abdomen, was irradiated, the temperature of the visceral organs was markedly elevated despite normal oral and rectal temperature. Studies with relatively low power levels showed that the rise in brain temperature is not the primary cause of death when the abdomen alone is irradiated, but the elevation of brain temperature is probably the primary cause of death when only the head is irradiated. Oldendorf, employing 12.5 cm microwaves, demonstrated that irradiation of the head of rabbits destroys brain tissue without apparent injury to the skin.

The cause of death from abdominal irradiation is usually attributed to shock; in other words, the mechanism of death is not understood. It is postulated that tissues respond to heat denaturation with an aseptic inflammatory reaction and are, as a consequence, prone to infection. This in turn may lead to peritonitis and shock. Boysen studied whole body radiation in experimental animals, using a 350 megacycles microwave generator with a power output of 5 to 500 watts. He observed hyperemia, hemorrhage, and necrosis in the bowels of irradiated animals and found the jejunum and ileum particularly susceptible to microwave radiation. Hyperemia of the spleen and hemorrhage into the myocardium were also observed. In addition, bloodless diarrhea ensued in each instance.

Although the precise temperature at which injurious effects are first noted has not been determined for all tissues, it is known that it varied for different tissues. It is well known that the testes undergo degenerative changes when maintained for a considerable period of time at a temperature equal to that found in the abdominal cavity. Severe testicular damage has been produced in animals by microwave irradiation. Studies of the effects of 12 cm microwaves upon the testes of adult rats have shown that a single 10 minute exposure caused testicular degeneration at a temperature of only 35 C measured in the central area of the gland. No evidence of any damage to the epidermis was found despite the pathologic changes which occurred in the interior of the gonads.

Cataract production is a frequently reported microwave injury. Microwaves of about 10 cm tend to produce maximum heating in tissue about one cm below the irradiated surface. Studies by Richardson, et al, showed that rabbit eyes exposed for 15 minutes at a distance of 5 cm from a 100 watt source of 12 cm microwaves developed lesions of the eye resembling cataracts in 3 to 9 days after the exposure. A series of repeated exposures to a lower power level at the same frequency produced cataracts in from 2 to 42 days. These cataracts varied from small posterior polar masses to almost complete